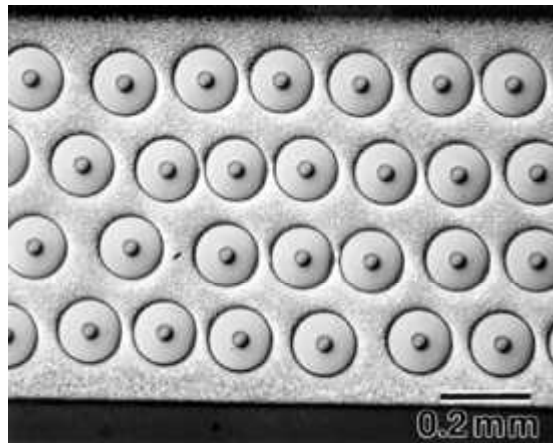


Orthorhombic Titanium Matrix Composite Subjected to Simulated Engine Mission Cycles

Titanium matrix composites (TMC's) are commonly made up of a titanium alloy matrix reinforced by silicon carbide fibers that are oriented parallel to the loading axis. These composites can provide high strength at lower densities than monolithic titanium alloys and superalloys in selected gas turbine engine applications. The use of TMC rings with unidirectional SiC fibers as reinforcing rings within compressor rotors could significantly reduce the weight of these components (ref. 1). In service, these TMC reinforcing rings would be subjected to complex service mission loading cycles, including fatigue and dwell excursions. Orthorhombic titanium aluminide alloys are of particular interest for such TMC applications because their tensile and creep strengths are high in comparison to those of other titanium alloys (ref. 2). The objective of this investigation was to assess, in simulated mission tests at the NASA Lewis Research Center, the durability of a SiC(SCS-6)/Ti-22Al-23Nb (at.%) TMC for compressor ring applications, in cooperation with the Allison Engine Company.

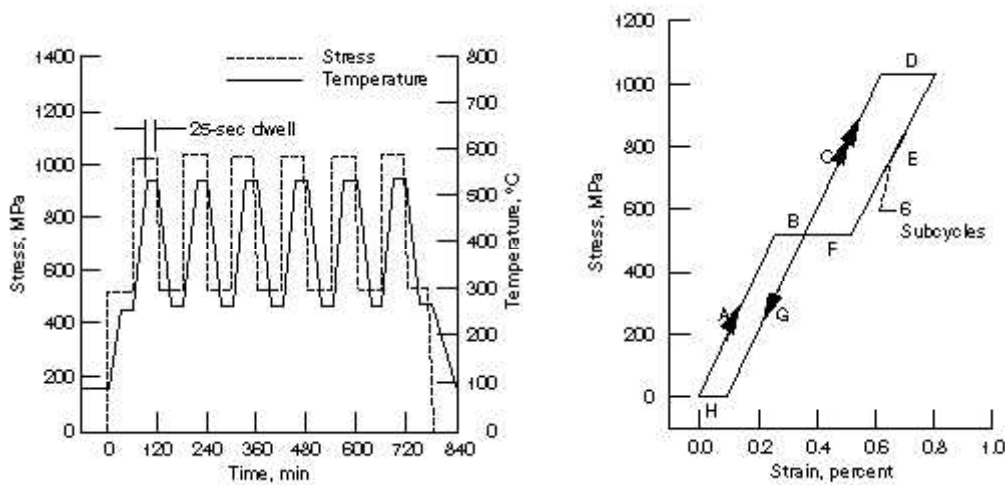
The composite consisted of Ti-22Al-23Nb (at.%) alloy reinforced by 41 vol % of unidirectional SCS-6 SiC fibers and consolidated by hot isostatic pressing. A typical specimen cross-section is shown in the photomicrograph. Specimens having a uniform reduced midsection with the fibers oriented parallel to the loading axis were machined and tested on a computer-controlled servohydraulic fatigue test system heated by a quartz lamp.



Typical cross section of an SCS-6/Ti-22Al-23Nb (at.%) composite panel.

Isothermal fatigue load-controlled tests were first performed at a frequency of 0.33 Hz, a temperature of 538 °C, and a maximum applied stress (S_{\max}) of 1035 MPa. The effects of a more realistic simulated mission cycle were then assessed. The Allison baseline mission cycle was designed to simulate aircraft engine operation in a simplified manner. The mission, illustrated in the left graph, is made up of a "Type I" major cycle and "Type III"

subcycles. The Type I cycle represents starting the engine, accelerating and stabilizing at maximum engine power at the beginning of an aircraft mission, and later shutting down the engine at the end of an aircraft mission. This cycle is simulated in the mechanical test specimen by an excursion from minimum temperature and zero stress through σ_{\max} and maximum temperature (T_{\max}), with a cyclic stress ratio (R_{σ}) of zero. Type III subcycles represent going from engine idle to maximum power, stabilizing at maximum power, then returning to idle at different times during a mission. This cycle is simulated in the mechanical test specimen by an excursion from intermediate stress and temperature through T_{\max} and σ_{\max} , with $R_{\sigma} = 0.5$. One total mission cycle is composed of one Type I and six Type III subcycles. Baseline conditions of $\sigma_{\max} = 1035$ MPa and $T_{\max} = 538$ °C were chosen for detailed evaluations. The right graph shows a typical stabilized stress-strain hysteresis loop with segment descriptions.



Left: Applied stress and temperature versus time in the Allison baseline mission cycle. Right: Typical stabilized stress-strain hysteresis loop of the baseline mission cycle. A-load at 93 °C; B-heat to 260 °C; C-load at 260 °C; D-heat to 538 °C, then dwell at σ_{\max}, T_{\max} ; E-unload at 538 °C; F-cool to 260 °C; G-unload at 260 °C; H-cool to 93 °C.

The average mission life was 1235 cycles, significantly lower than the average isothermal life of 8149 cycles in duplicate tests with the same maximum temperature and stress. The mission test specimens had fatigue cracks initiating from damaged fibers along the machined specimen edges, as in isothermal specimens. However, the percentage of fatigue-cracked area in mission tests was significantly lower than in isothermal tests. This appeared to be associated with a process of enhanced cyclic stress relaxation of the matrix during the mission. The process encouraged load transfer from the matrix to the fibers, which suppressed fatigue cracking and induced fiber overload. In future work, mission tests will be performed on orthorhombic TMC's that contain fibers with greater inherent strength.

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